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EFFECTS OF IRRIGATION WITH AMENDED DILUTIONS OF SEAWATER ON GERMINATION, GROWTH AND IONIC DISTRIBUTION IN *PENNISETUM DIVISUM* (GMEL.) HENR – AN ARID PSAMMOPHYTIC PERENNIAL GRAMINOID

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ABSTRACT

Germination, growth and ionic distribution in *Pennisetum divisum* (Gmel.) Henr. were investigated using 10-30% amended sea water (ECiw: 4.5-14.0 $dS.m^{-1}$) for irrigation. Fifty percent reduction in germination (in petriplates) corresponded with ECiw: 10.44 $dS.m^{-1}$ and threshold ECiw corresponding with 50% reduction in growth (in drum pot culture) was around 10.13 ± 1.01 $dS.m^{-1}$ (ranging from 8.57 to 12.25 $dS.m^{-1}$ when assessed in terms of root, residual shoot, harvested shoot and total plant biomass). The plant showed decline in regeneration after bi-monthly clipping around the year. The growth was extremely reduced during winter season (dormancy period). The cumulative forage biomass harvested per annum under 30 % amended seawater (14.0 $dS.m^{-1}$) was 1267.67 ± 234.67 $g.drum^{-1}$ (FW). It was 5467.0 ± 261.4 $g.drum^{-1}$ (FW) in control (1.2 $dS.m^{-1}$); reduction being c. 76.8%. The reduction in forage production in 10 and 20% seawater was c.48.3 and c.61.3%, respectively. The plant showed flowering throughout the year.

The plant irrigated with saline water showed decrease in chlorophyll and water content. Sugar contents remained statistically indifferent in leaves up to 20 % seawater irrigation but increased in 30% seawater. Although proline level increased considerably, protein concentration remained quite unaffected. Sodium increased in the roots as well as shoots. Potassium concentration which increased in roots of plants irrigated with 10% seawater, declined in 20 and 30 % seawater. It didn't vary in leaves up till 20% seawater. In leaves calcium declined at higher salinity. Mg concentration which increased in leaves (63.5%) of plants irrigated with low salinity declined in higher salinity but didn't vary significantly from that in the control plants. K / Na ratio was much higher in shoot and Ca/ Mg ratio was relatively higher in roots. Mg concentration was relatively higher in shoot than root of the treated plants.

Key-words: *Pennisetum divisum*, Amended saline (Seawater) irrigation, Germination, Growth, Biomass productivity, ionic Distribution.

INTRODUCTION

Pennisetum divisum (Gmel.) Henr., a perennial, psammophytic desert grass with suffruticosely branched and somewhat woody culms and woody underground rhizome, abounds with sand hills, grows in stony ground among rocks, in dry stream bed and on piled sand along the margins of dry salt marsh of Pakistan coast. It associates with salt free to marginally salt free sandy soils of ECe generally around 4.0 $dS.m^{-1}$ (Khan, 1987). It is a grass of high productive potential and is extensively grazed by desert animals.

Experimental investigations related to germination, growth, productivity and regeneration of *Pennisetum divisum* under saline irrigation are undertaken here to assess its salt tolerance and its possible scope in developing pasture under saline irrigation in sandy soils. Besides some important biochemical parameters of growth, studies in relation to cations distribution within plant are also undertaken. These studies are pertinent in view of the fact that many of the arid land perennial plants are drought-resistant in nature and they may acquire water held with high metric forces and utilize and retain water efficiently and conservatively (Moore *et. al*., 1972). Although various desert plants may vary with respect to the toxicity of different salts, owing to their capability to withstand high osmotic effects, salinity tolerance of desert plants / xerophytes may be thought to be higher than that of many agronomic species (McKell, 1979). Growing salt-tolerant, under-exploited plants by utilizing saline water for irrigation can provide an economic use of abandoned semi-arid and arid lands (Dagar *et al.*, 2006).

MATERIALS AND METHODS

(i) Preparation of Irrigation Media:

Different dilutions of sea water (10-30%), in order to reduce Na toxicity, were amended with fertilizer-mixture using Calcium Ammonium Nitrate (CAN), Single Super Phosphate (SSP) and Sulphate of Potash (SOP) in amounts appropriate to provide N:P:K ratio of 170 : 41:156. Magnesium was provided as Magnesium Sulphate. Micronutrients and Fe-EDTA each corresponding to half strength Hoagland's solution were added at the rate of 1ml per liter of culture solution to complete its composition. Control culture solution was prepared in tap water. The chemical analysis of the irrigation media appears in Table 1.

(ii) Germination:

The caryopses of *P. divisum* were collected from its population at Bhawani (off Balochistan coast). *P. divisum* seeds exhibited no dormancy. Its twenty surface-sterilized caryopses were placed on Whatman No. 1 filter paper in a 9 cm. diameter petriplates to germinate in a series of amended seawater dilution at 30 ± 1 ^{o}C with light intensity of 4000 Lux for 14h day-length. The control and treatments were replicated thrice. Germination counts were made daily.

(iii) Growth:

The plants of *P. divisum* were raised by vegetative propagation in poylethylene bags containing 1 kg sandy soil and provided with a basal perforation. The plants for this purpose were collected from Bhawani. The rooting medium was initially half strength Hoagland's solution and later the tap water provided at the alternate days till such a time that the plants were subject to pre-conditioning.

(a) Preconditioning:

In order to avoid the shock effects of saline irrigation, the plants after one month of growth in polyethylene bags were pre-conditioned by irrigating them initially with 5% amended sea water and gradually increasing the concentration up to a level in which the plants were to be finally grown.

(b) Drum Pot Culture:

Plastic drums were sunken in slightly slanting position in a cemented platform so as to ensure rapid drainage of saline water from the basal outlet. Each drum was filled with 300 kg of coastal sand collected from Sonmiani Beach (Balochistan). Each drum was capable of retaining 44 liters of water at field capacity. Over irrigation was practiced to avoid accumulation of salts in the root zone. Each drum was irrigated with 16 liters of irrigation medium at weekly interval, irrespective of any rains. Plants, being pre-conditioned when reached to a level of 10, 20 and 30% amended sea water, were transplanted in drum pots and irrigated with their respective concentration of seawater till the end of the experiment. Three replicates were kept for each treatment and the control. The experiment was continued for one year period.

The foliage biomass in terms of fresh weight was taken as a criterion of growth. Foliage was clipped after every two months interval at 30 cm. height from the soil. At the final harvest, residual shoot and root biomass were also recorded. Germination test of the caryopses produced by the plants grown under drum pot culture was also conducted in order to determine their viability and germinability.

(iv) Water Content and Biochemical Estimation:

Water content of the foliage was determined by the relative difference in fresh and dry weights of the sample and expressed as percentage of fresh weight. Chlorophyll (Maclachlam and Zalik, 1963), total sugars (Yemm and Willis, 1956), proteins (Lowry *et al.*, 1951), proline contents (Bates *et al*., 1973) of leaf were determined.

(v) Analysis of Mineral Ions:

Cations were extracted by acid digestion of 1g dry plant material following the method of Toth *et al*. (1948). The digestion was carried out in conc. Nitric acid followed by 72% Perchloric acid. The digested material was dissolved in 100ml deionized water. Na, K, Ca, and Mg were estimated using JARREL ASH-782-A Atomic Absorption Spectrophotometer. Three replicates were used for each treatment and control.

Table 1. Analysis of different dilutions of seawater after chemical amendments (data is a mean of 5 replicates).

Irrigation Medium	pH	EC_{iw}: $dS.m^{-1}$	Na (meq/l)	K (meq/L)	Ca + Mg (meq/L)	SAR
Control	7.35	1.2	3.26	1.27	32.43	0.63
10% SW + amendments	7.55	4.5	27.17	1.27	54.89	2.10
20% SW + amendments	7.45	9.5	32.82	3.19	69.86	6.04
30% Sw + amendments	7.45	14.0	131.52	3.83	109.78	11.11
Seawater (Arabian sea)	7.50	40.0	328.00	8.00	162.17	36.51

OBSERVATION AND RESULTS

Germination of *P. divisum* as well as the rate of the germination declined substantially under increasing salinity so that no germination occurred in 30% amended seawater under 48h of incubation (Fig. 1). The inhibition of germination in 30% seawater was c 80% as compared to that in control. The per cent relative final germination (Y) and the electrical conductivity of the irrigation medium (X, $dS.m^{-1}$) followed linear threshold response model of Maas and Hoffman (1977) as Y = 100 – 8.413 (Ke – 4.5) where Ke is the ECiw at which the % relative final germination is to be predicted. By this model 50% reduction in final germination corresponded with ECiw: 10.44 $dS.m^{-1}$.

Table 2. Fresh weight of shoot biomass (g) clipped from *P. divisum* as affected with seasonal variation and irrigation with amended dilutions of seawater.

TREATMENT	NOV-DEC Zero*	JAN-FEB 0.90	MAR-APR 47.60	MAY-JUN 0.50	JUL-AUG 106.80	SEP-OCT Zero
CONTROL	1133.33± 121.98 Ac	937.67± 19.20Aac	581.0± 140.0 Ab	863.33± 47.02 Aa	986.67± 35.28 Aac	965.0± 28.43 Aac
10% SEAWATER + AMENDMENTS	718.0 ± 141.63 Bab (-36.65)	454.67± 97.55 Bab (-51.51)	322.0± 100.1 ABa (-44.58)	326.67 ± 47.02 Ba (-62.16)	503.33 ± 116.67 Bab (-48.99)	500.0± 55.08 Bab (-48.19)
20% SEAWATER + AMENDMENTS	681.67 ± 636.36 Bb (-39.85)	306.8± 104.8 Ca (-67.28)	224.0 ± 67.56 Ba (-61.45)	194.66 ± 53.99B Ca (-77.45)	335.0 ± 96.74 BCa (-66.05)	348.33± 66.60 Ba (-63.90)
30% SEAWATER + AMENDMENTS	581.67± 63.89 Bc (-48.68)	234.33 ± 30.00 Cb (-75.01)	148.67 ± 26.35 Bab (-74.41)	68.67 ± 22.93 Ca (-92.05)	116.69 ± 61.67 Cab (-88.18)	117.67 ± 45.37 Cab (-87.81)

*, rainfall in mm; Figures in parenthesis indicate percent increase (+) or decrease (-) over control. Mean data not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT. Capital letters compares the columns and small letters the rows.

Table 3. ANOVA for seasonal harvests of *Pennisetum divisum grown* under various salinity regimes (amended seawater irrigation).

SOURCE	SS	Df	MS	F	p
Block/ Subject	25255.5	2			
Harvests	1543601.6	5	308720.32	13.359	0.001
Error (a)	231088.5	10	23108.85		
Treatment	49572000.2	3	1652400.09	22.05	0.001
Error (b)	449632.2	6	74938.71		
Harvest x Treatments	280187.2	15	18679.15	3.276	0.001
Error (C)	171039.9	30	5701.33		
Total	7658005.2	71			
Residual	851760.6	46			

CV (a) = 31.139; CV (b) = 56.075; CV (c) = 15.647 %. Grand mean = 488.19g

Table 4. Shoot biomass production (cumulative) per annum of *P. divisum* irrigated with various dilutions of amended seawater.

TREATMENT	BIOMASS HARVESTED ($g.drum^{-1}. yr^{-1}FW$)	RESIDUAL BIOMASS		TOTAL BIOMASS ($g.drum^{-1}. yr^{-1}FW$)
		Shoot (g)	Root (g)	
Control	5467.00 ± 261.4	486.67 ± 41.77	276.33 ± 46.83	6230.00 ± 304.32
10% Seawater + Amendments	2824.67 ± 410.74 (-48.33)	323.33 ± 49.19 (-33.56)	222.00 ± 9.87 (-19.66)	3370.33 ± 445.52 (45.91)
20% Seawater + Amendments	2117.13 ± 435.09 (-61.27)	253.33 ± 64.89 (-47.95)	140..00 ± 32.15 (-49.34)	2510.33 ± 520.04 (-59.71)
30% Seawater + amendments	1267.67 ± 234.28 (-76.81)	188.33 ± 20.48 (-61.30)	138.67 ± 30.69 (-50.05)	1594.67 ± 282.16 (-74.15)

Figures in parenthesis indicate per cent promotion (+) or reduction (-) over control.

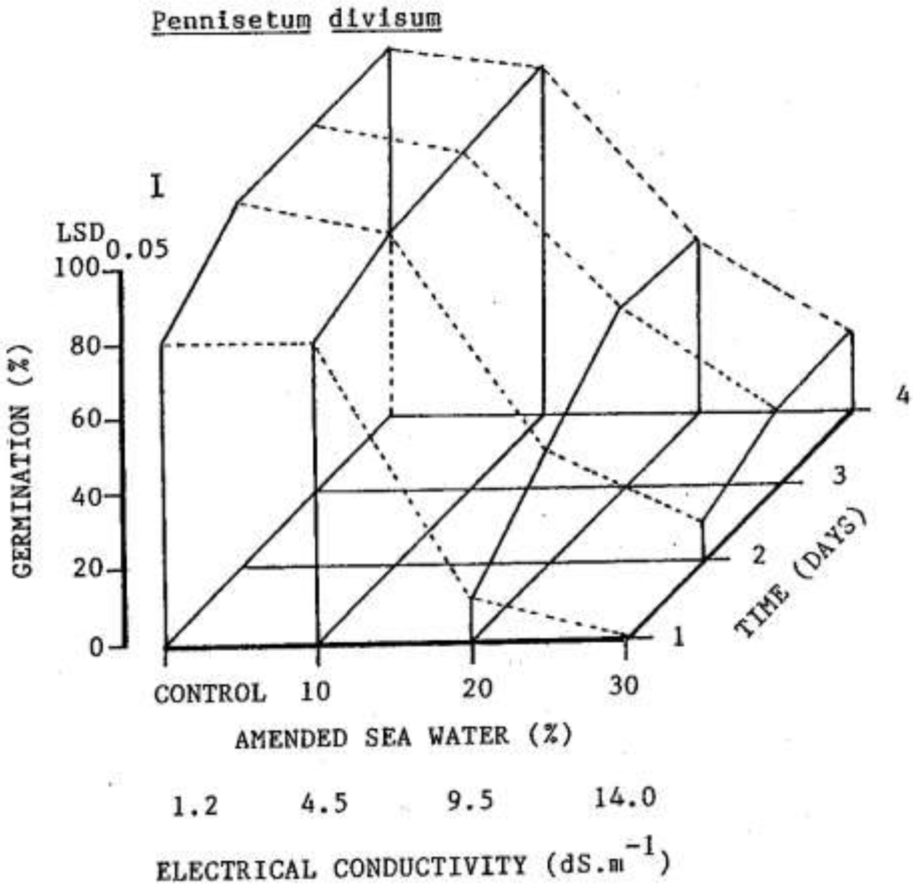

Fig.1. Germination response of *Pennisetum divisum* to various salinity regimes.

The increase in salts concentration in irrigation medium caused reduction in shoot biomass in all harvests round the year (Table 2). The maximum biomass was produced during the growth period of November – December. In this period the biomass of plants irrigated with 30% seawater reduced by 48.6% of the control. The biomass of control as well treated plants declined progressively up to summer harvest of May – June when the biomass at 30 % seawater was only 8% of the control. On the commencement of monsoon biomass though showed an increasing trend, it didn't differ significantly with the pre-monsoon harvest. It may probably be attributed at least partially to very low rain in this period. The plants exhibited flowering throughout the year. Its vegetative growth under high salinity regime was drastically inhibited and larger proportion of biomass came from reproductive structures. In spite of a large number of flowers produced, the seed setting was exceptionally low round the year. It, however, appears not to be related with the salinity as the control plants behaved similarly. The plant was noticed behaving similarly in the field.

The analysis of variance for the harvested biomass under different levels of salinity is given in Table 3. It showed that both harvest and treatment had significant effect on plant growth ($p < 0.001$) and there was also a significant interaction between treatment (salinity) and harvest ($p < 0.003$). The coefficients of variation for harvest effect (CV(a)), treatment effect (CV(b)) and interaction effect (CV(c)) were of low order indicating that the measurement of harvest, salinity and their interaction effects were of high and more and less equal precision.

Table 4 presents data on annual total biomass production. *P. divisum* appeared to be very productive grass under non-saline conditions. It, however, suffered from salt sensitivity and exhibited around 77% reduction in biomass over control in 30% seawater irrigation. The total harvested shoot biomass decreased progressively and significantly with the increase of salinity. Residual shoot and root biomass also exhibited more or less a similar pattern. The total biomass of the plant in 30% seawater irrigation (1594.7 ± 282.2 g per drum) was only 25% of the control plants (6230.0 ± 304.3 g per drum). Linear correlation and regression analysis between salinity and various growth parameters of *P. divisum* suggested that the threshold values of ECiw corresponding to 50% reduction growth (in terms of various growth parameters such as root, residual shoot, harvested and total plant biomass), ranged from 8.57 to 12.25 $dS.m^{-1}$ averaging to 10.13 ± 1.01 $dS.m^{-1}$ (Table 5). This threshold value is almost comparable to that corresponding with 50% reduction in final germination (ECiw: 10.44 $dS.m^{-1}$).

The plant irrigated with saline water showed decrease in chlorophyll content but no significant change in ratio of chlorophyll a and b was observed. Water content of the plant was significantly reduced (around 9%) under 30% seawater irrigation. The contents of total sugar in leaves remained statistically indifferent up to 20% seawater irrigation but increased in 30% seawater (Table 6). Protein content did not vary significantly, though proline increased considerably (c. 50%) in plants irrigated with 30% seawater.

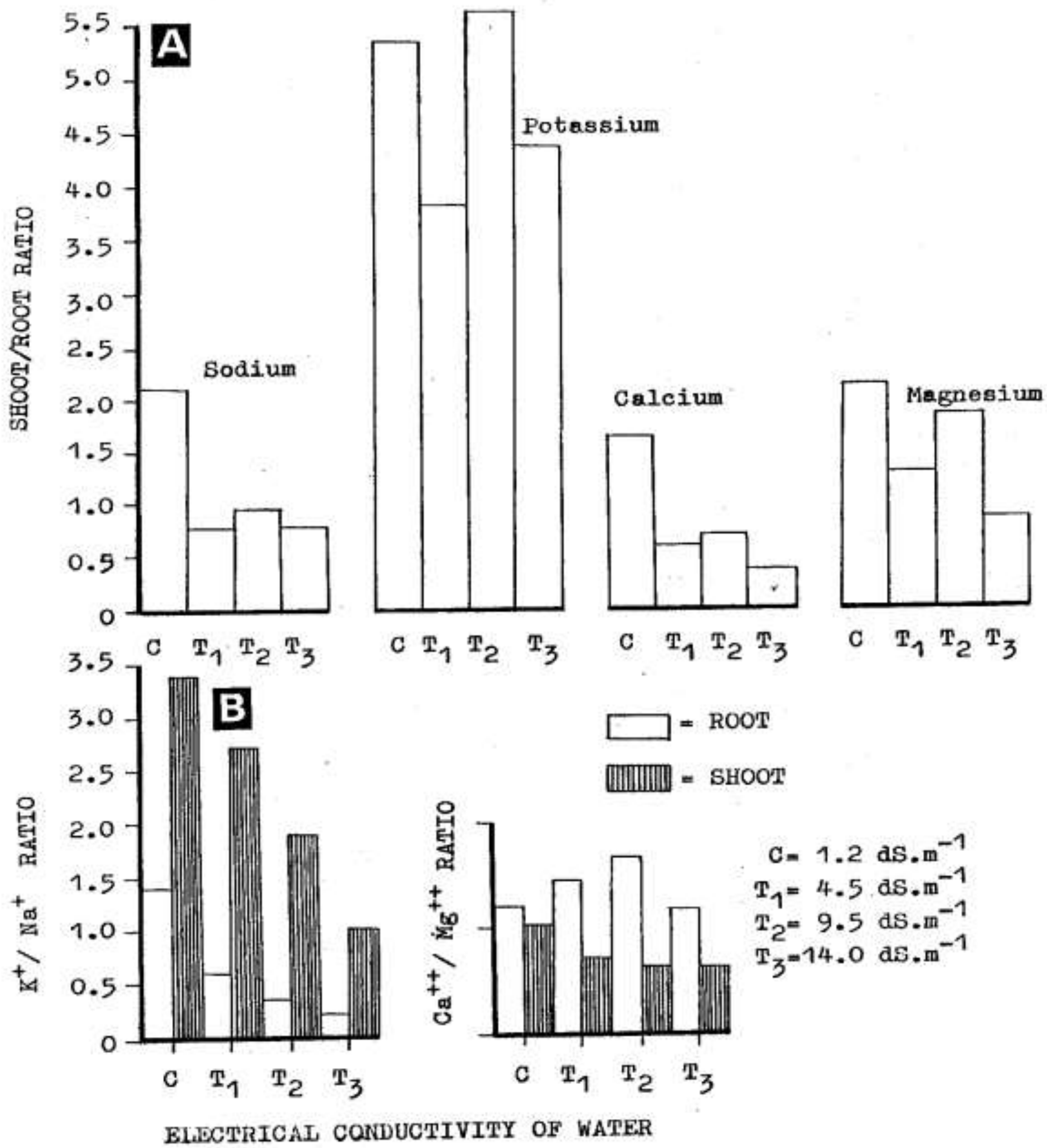

Fig.2. Coparative account of ions in root and shoot (A) and K+ / Na+ and Ca++ / Mg++ ratios in root and shoot (B) of *Pennisetum divisum* grown under various salinity regimes.

The data on cationic composition of root and leaves indicated that Na increased in leaves as well as in roots of the treated plants (Table 7). K, which significantly increased in root of plants irrigated with 10% seawater, declined in 20 and 30% seawater. K didn't vary in leaves up to 20% seawater but decreased appreciably in plants grown with 30% seawater irrigation. Ca and Mg increased in roots of treated plants substantially. In leaves, Ca declined at higher salinity. Mg concentration which increased (63.5%) in leaves of plants irrigated with low salinity declined in higher salinity but didn't vary significantly from that in the control plants. *P. divisum* had higher K / Na ratio in shoot in comparison to that in the roots (Fig. 2). Shoot / root ratio of Na remained less than one in magnitude in treated plants indicating somewhat more accumulation of Na in roots. K / Na ratio was much higher in shoot and Ca/ Mg ratio was relatively higher in roots.

DISCUSSION

Our studies indicated that germination of *Pennisetum divisum* declined against salinity in accordance with linear threshold model of Hoffmann and Mass (1977) and its growth declined simply linearly with salinity. The electrical conductivity of irrigation water corresponding to 50% reduction in germination and growth was, however, comparable (~ 10 dS.m-1). Salt tolerance at germination and other phases of life cycle are generally not necessarily correlated and with the exception of *Hordeum jubatum* (Ungar, 1974) and *Sporobolus arabicus* (Khan and Ahmad, 2002) seeds are generally more vulnerable to salinity than adult plants (Ayers, 1952; Mayer and Poljakoff-Mayber, 1975; Khan and Ahmad, 1998, 2007) - even in case of several halophytes (Azizov, 1974; Prado *et al*, 2000; Gulzar *et al*, 2001; Joshi *et al.*, 2005). Based on 50% reduction in germination and growth, the degree of salt tolerance of *Pennisetum* was similar to that of *Indigofera oblongifolia* (Khan and Ahmad, 1998).

Table 5. Linear correlation and regression between electrical conductivity (ECiw: dS.m-1) of irrigation water and various growth parameters of *Pennisetum divisum*.

ECiw: dS.m^{-1} (X) / Parameter Studies (Y)	r	Regression		ECiw: dS.m^{-1} Corresponding to 50% reduction	Average ECiw: dS.m^{-1}
		a	b		
ECiw / biomass Clipped	- 0.8771 ***	5083.91	- 296.55	8.57	10.13 ± 1.01 CV= 7.54 %
ECiw / Residual Shoot Biomass (g) FW	- 0.8158 ***	471.18	- 21.68	10.87	
ECiw / Root Biomass (g) FW	- 0.7399***	276.67	- 11.29	12.25	
ECiw / Total Biomass (g) FW – including Root Biomass	- 0.8783 ***	5831.76	- 329.52	8.85	

CV, Coefficient of variation; ***, $p < 0.001$, N = 12.

Table 6. Effect of amended seawater irrigation on the chlorophyll, moisture and biochemical constituents of *P. divisum* leaves.

Treatment	Chl. A mg.g^{-1}FW	Chl. B mg.g^{-1}FW	Total Chl. mg.g^{-1}FW	Chl. a / b ratio	Moisture (%)	Total Sugars mg.g^{-1}DW	Protein mg.g^{-1}DW	Proline mg.g^{-1}DW
Control	0.390 ± 0.017 a	0.457 ± 0.039 a	0.847 ± 0.055 a	0.859 ± 0.040	76.62 ± 0.79 a	34.36 ± 2.084 a	50.943 ± 0.803 a	0.920 ± 0.056 a
10% SW +A	0.300 ± 0.035 a (-23.07)	0.341 ± 0.051 b (-25.38)	0.641 ± 0.079 b (-24.32)	0.904 ± 0.120 (+5.23)	77.32 ± 0.627 a (+0.92)	42.17 ± 4.953 ab (+22.72)	52.746 ± 2.219 a (+3.539)	1.122 ± 0.122 b (+21.95)
20 % SW+ A	0.328 ± 0.012 a (-15.89)	0.352 ± 0.016 b (-22.97)	0.680 ± 0.030 (-19.71)	0.934 ± .032 b (+89.73)	72.46 ± 3.236 ab (-5.43)	39.745 ± 2.345 ab (+15.56)	41.533 ± 4.383 a (-18.47)	1.205 ± 0.196 b (+9.24)
30 % SW+ A	0.285 ± 0.032 a (-26.92)	0.309 ± 0.051 b (-32.38)	0.594 ± 0.079 (-29.87)	0.945 ± 0.104 b (+10.01)	69.698 ± 1.606 b (-9.03)	41.966 ± 1.552 b (+22.14)	49.978 ± 2.512 a (-1.89)	1.462 ± 0.179 c (+58.91)

Mean data in column not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT.
Figures in parenthesis indicate percent increase (+) or decrease (-) over control. Chl., Chlorophyll; SW +A, Amended seawater

P. divisum although appeared very productive on forage yield basis in control, suffered from relatively high salt sensitivity to the extent that forage yield even at low salinity level (10% amended seawater) declined around 48%

over the control. At high salinity level (30% seawater the growth declined by 77% of the control but even at this level, the amount of biomass produced (1.27 ± 0.25 kg/ drum/year DW) was more or less equal to that of *Leptochloa fusca* (1.28 kg /drum / year DW) (cf. Ahmad *et al.*, 1985) grown under similar conditions. This may probably be attributed to very rapid growth rate of *Pennisetum*. The regeneration in this species after clipping was mainly by sprouting of buds situated on the underground rhizome and little by the aerial axillary buds. Regeneration from underground buds under salinity is substantially affected and decline of harvested biomass by 50% occurred at ECiw: 8.57 $dS.m^{-1}$. The plant is of great forage value in many desert and semi desert regions (Dr. M. Zarough, personal communication). Its scope in fodder production through biosaline technique appears to be limited due to its salt sensitivity. However, it may give substantial yield under irrigation with low salinity water (below 8 dS.m-1).

Table 7. Effect of amended seawater irrigation on cationic composition of *P. divisum* roots and leaves.

Treatment	Sodium (meq /l)		Potassium (meq / l)		Calcium (meq/l)		Magnesium (meq / l)	
	Root	Leaves	Root	Leaves	Root	Leaves	Root	Leaves
Control	0.928 ± 0.058 a	2.029 ± 0.145 a	1.287 ± 0.081 a	6.948 ± 0.698 a	0.317 ± 0.060 a	0.517 ± 0.033 a	0.529± 0.079 a	1.151 ± 0.063 a
10% SWA	3.551 ± 0.145 b (+282.65)	2.898 ± 0.290 b (+42.83)	2.088 ± 0.183 b (+62.23))	7.886 ± 0.259 a (+13.50)	1.033 ± 0.017 b (+226.31)	0.617± 0.067 a (+19.34)	1.444 ± 0.191 bc (+172.41)	1.882 ± 0.143 bc (+63.48)
20 % SWA	3.406 ± 0.627 b (+267.02)	3.333 ± 0.363 b (+64.26)	1.129± 0.139 c (-12.23))	6.308 ± 1.413 a (-9.21)	0.617± 0.217 b (+94.88))	0.448 ± 0.051 a (-13.34)	0.841 ± 0.211 b (+58.61)	1.572 ± 0.256 ab (+36.50)
30 % SWA	3.768 ± 0.316 b (+306.03)	2.956 ± 0.822 b (+45.68)	0.742± 0.193 d (-42.37)	3.197 ± 0.369 b (-53.98)	0.866 ± 0.183 b (+173.53))	0.283± 0.060 b (-45.20)	1.553 ± 0.292 c (+193.09)	1.023 ± 0.143 a (-11.11)

Mean data in column not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT. Figures in parenthesis indicate percent increase (+) or decrease (-) over control. SW + A, Amended seawater.

The plant irrigated with saline water showed decrease in chlorophyll content but no significant change in ratio of chlorophyll a and b was observed. It could be due to salinity-induced inhibition of iron-containing enzymes which activates the biosynthesis of chlorophyll as suggested by Rubin and Artiskhovaskaya (1964). Water content of the plant was significantly reduced (around 9%) under 30% seawater irrigation. The contents of total sugar in leaves remained statistically indifferent up to 20% seawater irrigation but increased in 30% seawater. Reports on sugar accumulation under salinity are controversial. Rozema (1978) reported larger increase in sugar concentration under salinity stress in relatively salt sensitive species, *Juncus alpinoarticularis* ssp. *articappilus*. Shannon and Qualset (1984) reported that accumulation of sugar in leaf is generally larger in salt excluding plant. Khan (1998) reported significant promotion in sugar accumulation in salt excretive *Sporobolus arabicus*. Relatively salt tolerant legume, Indigofera oblongifolia (reducing growth by 50 % at ECiw: 12.05 ± 0.92 $dS.m^{-1}$) also showed increase of sugar level in leaves, which became fleshy with age under saline environment (Khan and Ahmad, 1998). A moderately salt tolerant grass *Panicum turgidum* with tendency of excluding Na from shoot, on the other hand, showed substantial decrease in foliar sugar level under salinity (Khan and Ahmad, 2007). However, it is certain that sugars not only serve as resource food materials but also serve as cellular osmoticum (Shannon, 1984; Jeffereies *et. al.*, 1979), besides proline, glycinebetaine and other organic solutes.

Protein content did not vary significantly, though proline increased considerably (c. 50%) in plants irrigated with 30% seawater. The homeostatic control, with respect to the protein synthesis and its breakdown, appears to be relatively more effective in this species where no significant change in protein content of salinity-treated plants was observed. So far accumulation of proline is concerned; it appears to be due to both the osmotic as well as ionic effects of salts as the moisture contents of the plant declined significantly along the rise of ionic contents in leaves under salinity. Proline has been reported to increase in concentration under different stressful conditions and its accumulation in saline environment (Rozema, 1978; Strogonov, 1962; Rains *et al.*, 1982; Joshi *et al.*, 2005) is considered beneficial for plant growth (Rozema, 1978; Strogonov, 1962; Rains *et al.*, 1982). Proline accumulation may take place either due to protein degradation or inhibition of proline conversion under salinity (Singh *et. al.* 1973). It is assumed that proline increases the protein solubility (Schobert and Tschesche, 1978), it is compatible in permeability to cytoplasm and prevents the dehydration of enzymes and other essential structures (Gorham *et al.*,1981), it controls the ion-fluxes (Stewart and Lee, 1974) and regulates the storage of nitrogen (Jeffereies, 1980).

The ability of *P. divisum* to survive and persist in moderately to highly saline conditions appears to be related with reduced salt uptake and differential rates of ions translocation. Albert and Kinzel (1978) have reported low uptake of NaCl in general in monocotyledonae. Our experiment disclosed a differential preference of cations uptake. In spite of Na being present in larger concentration in the irrigation medium, the plant managed to absorb K, Ca and Mg due to selective permeation operating in the roots. The data on cationic composition of root and leaves indicated that Na increased in roots and leaves of the treated plants. *P. divisum* had much higher K / Na ratio in shoot in comparison with that in the roots. It may, therefore be rated as a potassiophillic plant with some tendency of sodium exclusion from leaves by retaining it in roots as indicated by shoot / root ratio of Na being less than one in magnitude in salinity treated plants. Ca and Mg increased in roots of treated plants substantially. In leaves, Ca declined at higher salinity. Mg concentration which increased (63.5%) in leaves of plants irrigated with low salinity declined in higher salinity but didn't vary significantly from that in the control plants. Calcium was more retained in roots. Lazaroff and Pitman (1966) had also reported that *Hordeum vulgare* shoots show preference to Mg whereas Ca is more preferentially accumulated by the roots. These results are, however, contrary to those reported by Ahmad and Zaheer (1985) for dicotyledonous plants like *Zygophyllum simplex*, *Hammada recurva*, *Cressa cretica* and *Heliotropium curassavicum*, when growing in highly saline soils. These plants were reported to accumulate greater amounts of Ca in shoot. It may also be pointed out that uptake of divalent cations (Ca and Mg) is largely proportional to the concentration of these ions in the culture medium (Lazaroff and Pitman (1966). Substantial concentration of Ca and Mg in the tissues of *P. divisum* could be due to the enrichment of irrigation medium with these ions to reduce sodium toxicity. The amendments employed to ameliorate the concentration of K, Ca, and Mg in the irrigation medium could have retarded the movement of sodium and have intensified the availability and uptake of K, Ca, and Mg. It is known that K-Na exchange and selective uptake of K depend upon the presence of Ca in the rooting medium (Ezlam and Epstein, 1969).

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